# Describing Soils: Calibration Tool for Teaching Soil Rupture Resistance

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**ABSTRACT** Rupture resistance is a measure of the strength of a soil to withstand an applied stress or resist deformation. In soil survey, during routine soil descriptions, rupture resistance is described for each horizon or layer in the soil profile. The lower portion of the rupture resistance classes are assigned based on rupture between thumb and forefinger. The tactile sense of the pressure can vary considerably between individuals. A calibration tool was developed, to help the students and soil scientists calibrate their thumb and forefinger for the correct amount of pressure. Instructions on how to assemble four pressure calibration tool assemblies measuring 8, 20, 40, and 80 N of applied pressure are presented. The calibration tools are demonstrated on how the combinations of spring/knobs are put together to get different rupture pressures. Manufactured or substitute fragments for natural fragments can be used in the instruction of rupture resistance in the classroom. In soil survey, this tool has been effective in calibrating the finger-force range for rupture resistance class placement for the last two decades.



The term soil consistence describes the resistance of a soil to mechanical stresses or to deformation. In soil survey, consistence is a means of describing the degree and kind of cohesion and adhesion between soil particles as related to the resistance of the soil to deform (Soil Survey Division Staff, 1951). Consistence is commonly measured by feeling the soil, reflecting relative resistance to pressure (e.g., friable, firm), and depends on the moisture content. Measurement of consistence is conducted at one or more of three moisture contents (i.e., dry, moist, and wet). Wet consistence is evaluated by the degree of soil stickiness and plasticity (Soil Survey Division Staff, 1951). Consistence has importance in evaluating soil quality, and other uses such as seedling emergence, soil tillage, and compaction by farm machinery. Soil hydraulic properties are also affected by consistence, which can serve as a predictor of soil water retention (Rawls and Pachepsky, 2002). In soil survey, during routine soil descriptions, soil consistence is described for each horizon or layer in the soil profile. In 1993, soil consistence descriptions went through a major change when the Soil Survey Manual was updated (Soil Survey Division Staff, 1993). Soil consistence (relating to dry and moist descriptions) was changed to rupture resistance. Stickiness and plasticity were retained as independent measures from rupture resistance. Descriptions of soil consistence currently include soil rupture resistance, stickiness, plasticity, resistance to penetration, and manner of failure (Schoeneberger et al., 2002).

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Before 1993, consistence classes for moist and dry soils were described by subjective, adjectival phrases that allowed a considerable range in interpretation (Soil Survey Division Staff, 1951). The tactile sense of the class limits for consistence could vary greatly between pressures, and it was expected that the class placement of soil fragments into the various consistence classes would be highly variable among field soil scientists. Grossman and Bartelli (1957) set out to test the variability between 20 field soil scientists from the western part of the United States in estimating consistence. A hand-dynamometer that could measure force exerted between the thumb and forefinger was used. Four consistence class separations were assessed (i.e., soft to slightly hard, slightly hard to hard, friable to firm, and firm to very firm). Results showed a high degree of variability among soil scientists. The study indicated that field soil scientists could be trained and that it was possible to place objective limits on the subjectively defined soil consistence classes. In a later study, Nettleton et al. (1969) had shown 60% agreement between soil scientists in consistence descriptions for moist soils and 70% for dry soils. Another study was conducted to determine the force exerted between thumb and forefinger at limits of the moist consistence classes (Grossman, unpublished data, 1971). Spring assemblies were used that differed in force (i.e., ½, 1, 2, 4, 6, 8 kg force) necessary to compress thumb and forefinger together from the same standard thickness of about 3.0 cm. A spring assembly consisted of a rubber stopper on each end of a common compression spring. The force was measured when the rubber stoppers just touched. Soil scientists were asked to place the various spring assemblies on a scale from very friable to extremely firm moist consistence. The results of this study were used to quantitatively develop the moist rupture resistance system in the current Soil Survey Manual (Soil Survey Division Staff, 1993). When developing the new system, the previous consistence terms and class limits were utilized

**Table 1.** USDA-NRCS rupture resistance classes.†

| Classes | | | Test description | |
|---|---|---|---|---|
| Moderately dry and very dry | Slightly dry and wetter | Air dried, submerged | Operation | Stress applied‡ |
| Loose | loose | not applicable | specimen not obtainable | |
| Soft | very friable | uncemented | fails under very slight force applied slowly between thumb and forefinger | <8 N |
| Slightly hard | friable | extremely weakly cemented | fails under slight force applied slowly between thumb and fore-finger | 8–20 N |
| Moderately hard | firm | very weakly cemented | fails under moderate force applied slowly between thumb and fore-finger | 20–40 N |
| Hard | very firm | weakly cemented | fails under strong force applied slowly between thumb and forefinger (80 N about maximum force that can be applied). | 40–80 N |
| Very hard | extremely firm | moderately cemented | cannot be failed between thumb and forefinger but can be between both hands or by placing on a nonresilient surface and applying gentle force underfoot. | 80–160 N |
| Extremely hard | slightly rigid | strongly cemented | cannot be failed in hands but can be underfoot by full body weight (ca. 800 N) applied slowly. | 160–800 N |
| Rigid | rigid | very strongly cemented | cannot be failed underfoot by full body weight but can be by <3 J blow. | 800 N–3 J |
| Very rigid | very rigid | indurated | cannot be failed by blow of <3 J. | ≥3 J |

† Source: Soil Survey Division Staff, 1993.
‡ Both force (newtons, N) and energy (joules, J) are employed. The number of newtons is 10 times the kilograms of force. One joule is the energy delivered by dropping a 1 kg weight 10 cm.

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to the maximum extent possible and rupture resistance on wet soils was added.

The rupture resistance classes are quantitatively defined for block-like and plate shaped specimens and are defined based on the amount of force needed for failure (e.g., <8 N for very friable or soft depending on the moisture state). Estimates of rupture resistance are made on soil structural fragments such as blocks, peds, and clods; and surface crusts and plates that range from 2.5 to 3.0 cm on edge in size (Soil Survey Division Staff, 1993). Estimates are made for dry, moist, and wet soils. The fragments are compressed between extended thumb and forefinger, between both hands, or between the foot and a nonresilent flat surface. Rupture resistance is also applied in determining the degree of cementation. To test for cementation, an air-dry fragment is placed in water for 1 hour and the rupture resistance determined while still wet. Pressure is applied until deformation or rupture of the fragment. The classes of rupture resistance are described in the Soil Survey Manual (Soil Survey Division Staff, 1993) and reproduced here in Table 1. Soil rupture resistance is currently defined as the measure of the strength of a soil to withstand an applied stress or resist deformation (Schoeneberger et al., 2002).

Teaching a soil scientist to exert the right amount of pressure for placement of fragments into the rupture resistance classes can be difficult and thus makes rupture resistance class placement subjective. However, the tactile sense of the class limits can be learned. A calibration tool was developed to help student soil scientists calibrate their thumb and forefinger for the correct amount of pressure (Fig. 1), and to teach the class separations in the finger force range. For forces applied with the foot (>80 N) a scale can be used to calibrate foot pressure. The aim of this article is to present a simple, effective method for teaching tactile rupture resistance class limits as well as directions for assembling the calibration tool.

# Materials and Methods

## Calibration Tool Assembly

Four pressure calibration tool assemblies that measure 8, 20, 40, and 80 N of applied pressure are constructed (Fig. 1). These pressures correspond to the very friable–friable, friable–firm, firm–very firm, and very firm–extremely firm breaks in the moist rupture-resistance classes of block like specimens (Table 1). Each assembly consists of two doorknobs (BP3413-3; Amerock Corp, Rockford, IL), a compression spring (no. 67; Jones Spring Company, Cincinnati, OH), and fully threaded flat head hex socket cap screws (8–32 by 9.52 mm, 12.7 mm, and 19.0 mm) as needed

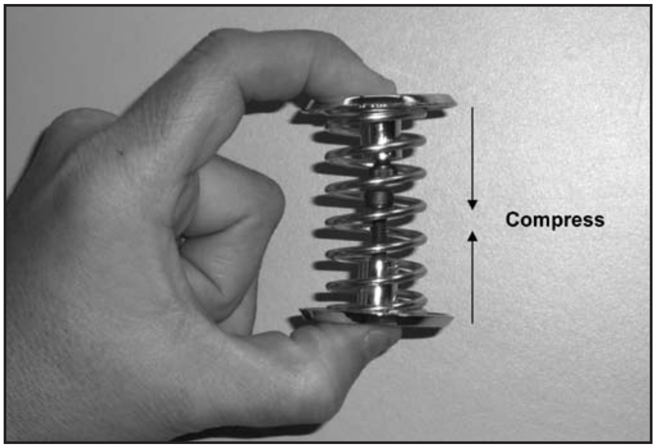


**Fig. 1.** A tool to calibrate the finger-force range in determining the rupture resistance class of soil fragments. The thumb and forefinger compress the spring until the doorknobs with screw caps just touch.

(Fig. 2). On each end of the compression spring, doorknobs are placed. The assembly is compressed between thumb and first finger (Fig. 1). The cap screws are adjusted so that the desired force is exerted just as the cap screws touch the doorknob or other cap screw. The cap screws differ in height for each assembly. For the 80 N pressure, two doorknobs without cap screws are used to get double the applied pressure. The desired force exerted is when the two doorknobs just touch (Fig. 1). Pressure applied by the fingers should be over a 1-second period.

*Calibration Tool—8 N Assembly*

1. Mount a 9.52 mm cap screw in one doorknob. Screw down the cap screw tightly into the doorknob. Label doorknob as no. 1.
2. Mount a 19.0-mm cap screw in a second doorknob. Add epoxy and screw in one turn. Label doorknob as no. 2.
3. Place a compression spring between the two doorknobs with cap screws facing each other.
4. Place the doorknobs with mounted cap screws and spring on a top loading balance. Adjust the 19.0-mm cap screw until 800 grams is exerted where the two cap screws just touch (Fig. 3). Do this before epoxy dries.

*Calibration Tool—20 N Assembly*

5. Mount a 12.7-mm cap screw in a third doorknob. Apply epoxy and screw in one turn. Label doorknob as no. 3.
6. Place a compression spring between no. 1 and 3 doorknobs with cap screws facing each other.
7. Place the doorknobs with mounted cap screws and spring on the top loading balance. Adjust cap screw (on no. 3 doorknob) until 2000 grams is exerted where the two cap screws just touch. Do this before epoxy dries.

*Calibration Tool—40 N Assembly*

8. Mount a 9.52-mm cap screw in a fourth doorknob. Apply epoxy and screw in one turn. Label doorknob as no. 4.

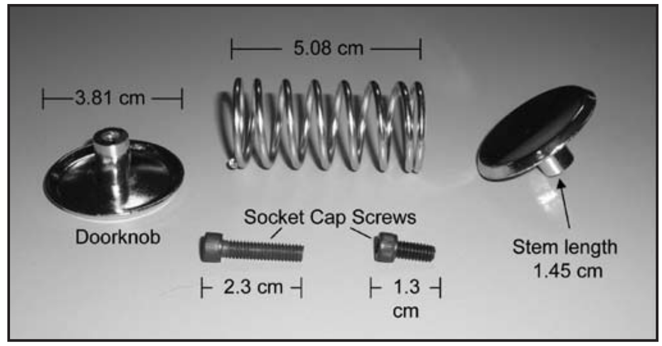


**Fig. 2.** Two 3.81-cm diameter doorknobs (model BP3413-3; Amerock Corp, Rockford, IL), a 5.08-cm compression spring (no. 67; Jones Spring Company, Cincinnati, OH), and three sizes of socket head cap screws (8–32 by 9.52 mm, 12.7 mm, and 19.0 mm lengths) are used in the construction of the calibration tool assemblies.

9. Place a compression spring between no. 1 and 4 doorknobs with cap screws facing each other.
10. Place the doorknobs with mounted cap screws and spring on the top loading balance. Adjust cap screw (on no. 4 doorknob) until 4000 grams is exerted when the two cap screws just touch. Do this before epoxy dries.

*Calibration Tool—80 N Assembly*

11. Place a compression spring between two doorknobs without cap screws. Label the doorknobs no. 5 and 6.
12. Place the doorknobs and spring on the top loading balance. If 8000 grams is exerted when the two cap screws just touch, the assembly is complete. Otherwise, grind down one of the doorknob posts until 8000 grams is exerted when the two posts just touch.


**Fig. 3.** A calibration tool is being calibrated so that the desired force is exerted when the two doorknobs just touch. The reading on the scale is noted when the two doorknobs just touch, then adjustments are made to the cap screws until the desired reading is obtained.

**Table 2.** Directions for assembling a set of calibrations tools to obtain the desired force.

| Doorknob no.† | Force |
|---|---|
| | N |
| 1 and 2 | 8 |
| 1 and 3 | 20 |
| 1 and 4 | 40 |
| 5 and 6 | 80 |

† Springs and doorknobs are not interchangeable between sets.

The doorknobs are labeled 1 through 6 and are kept together as a set (Table 2). Note that the assemblies are made for a particular spring and are not interchangeable between sets. The calibration tool maximum is 80 N of force. Beyond 80 N, fragments are crushed under foot on a solid surface. To teach the correct foot pressure to apply to a fragment, a bathroom scale can be used. A fragment is placed on the scale (Hanson Multi purpose scales, 11.3 kg capacity) and crushed under foot, noting the weight reading when the fragment just ruptures (Fig. 4). Several tries may be needed to get an average reading. The force exerted in kilograms or pounds is converted to newtons (N).

$$1.0 \text{ kg (of force)} = 9.80665 \text{ N}$$

$$1.0 \text{ lb (of force)} = 4.44822 \text{ N}$$

If the fragment resists rupture by compression, a weight is dropped onto it from increasingly greater heights until rupture (not discussed in this article). Failure is at the initial detection of deformation or rupture.

### Fragments

Natural or fabricated fragments can be used in the instruction of tactile training for rupture resistance. Natural soil fragments, 25 to 30 mm on edge, can be collected from different soils or from different horizons (or layers) within a soil profile. Soil fragments can also be fabricated to a desired rupture resistance by making soil slurries and pouring them into small cubed or rounded ice trays, and then allowing them to air-dry. Slurries can be made by adding tap water to soil in amounts just enough so the soil slurry flows after stirring. The fabricated peds can be removed from the ice trays similar to removing ice (twisting the trays). However, the peds need to be removed gently to avoid breakage. For weaker peds, place a piece of cardboard over the top of the ice tray and gently flip the tray upside-down holding the cardboard intact. Place the upside-down tray on the counter and tap lightly, the top of the tray with your finger, until all the peds have fallen out. Drying may take several days depending on humidity and soil type. To get different rupture resistances of the fabricated peds, vary the mixture of a sandy and loamy soil, or

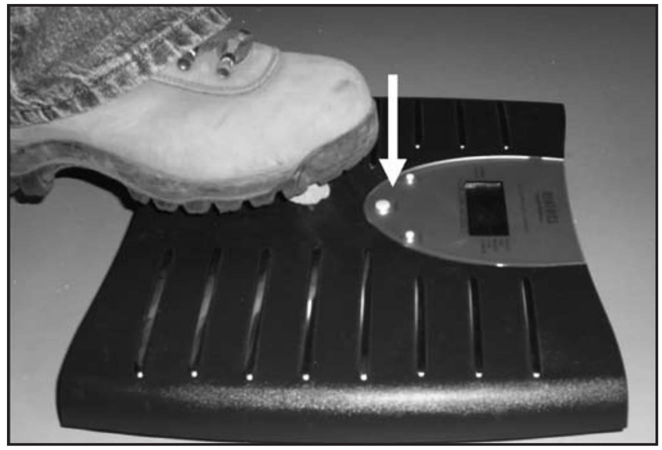

**Fig. 4.** Pressure is applied to a fragment with the foot until rupture. The reading on the scale at rupture is noted.

sandy and silty-clay loam soil (Ibanga et al., 1980). Some experimentation may be needed on the proportions of the different soils needed to get the desired rupture resistance. Table 3 describes soil types used to get five different levels of rupture resistance. Also, non-soil fragments can be used in the instruction of rupture resistance. In general, air-dried bread fragments can give a slightly hard, and air-dried bagel fragments can give a very hard rupture resistance. Fruit Loops (Kellogg's cereal) have varying rupture resistance values. All of the above are examples of fragments that can be used for training.

## Instructional Uses

The tactile sense of the class limits may be learned by calibrating the fingers to apply the correct amount of force using the calibration tool assemblies and foot pressure through the ball of the foot by using bathroom scales. In a classroom setting, each student is given a set of calibration tools (with instructions) for the finger force range and a bathroom scale for the foot pressure range. The calibration tools are demonstrated on how the combinations of spring/knobs are put together to get different rupture pressures. A bathroom scale is provided to calibrate rupture between foot and a nonresilient surface. Instruct students to cali-

**Table 3.** Selected properties of soils that fall within a certain rupture resistance range when fabricated fragments from these soils are air-dried.

| Soil series† | Horizon | Sand | Silt | Clay | OC | Force |
|---|---|---|---|---|---|---|
| | | % | | | | N |
| Walla Walla | A | 18.5 | 66.4 | 15.1 | 1.28 | <8 |
| Naron | C | 53.3 | 24.9 | 21.8 | 0.14 | 8–20 |
| Malbis | Bt | 45.9 | 29.2 | 24.9 | 0.18 | 20–40 |
| Crider | A | 1.6 | 79.3 | 19.1 | 1.00 | 40–80 |
| Houston Black | A | 4.7 | 35.9 | 59.4 | 3.16 | >80 |

† Walla Walla is a coarse-silty, mixed, superactive, mesic Typic Haploxerolls; Naron is a fine-loamy, mixed, superactive, mesic Udic Agriustolls; Malbis is a fine-loamy, silicious, subactive, thermic Plinthic Paleudults; Crider is a fine-silty, mixed, active, mesic Typic Paleudalfs; Houston Black is a fine, smectitic, thermic Udic Haplusterts.

brate fingers using the spring assemblies then determine rupture resistance on unknown fragments provided. If fragments cannot rupture in the hand, then foot pressure is applied to the fragment on the bathroom scale. The students are asked to convert the measurements from pounds to newtons and place the fragments in classes in Table 1.

Spring assemblies have been in use in the USDA-NRCS basic soil survey courses for the past 20 years. Student evaluations regarding use of the calibration tools for tactile training have been very favorable. Comments such as "I actually learned something useful" and "this is something I can take back to the survey" have been frequently reported. The assemblies can also be useful in training students to obtain the proficiency level for rupture resistance for soil judging (Ponte and Carter, 2000). The calibration tools have become a part of the tool set carried by field soil scientists for use when describing soils.

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